Adaptive Vehicle Make (AVM)

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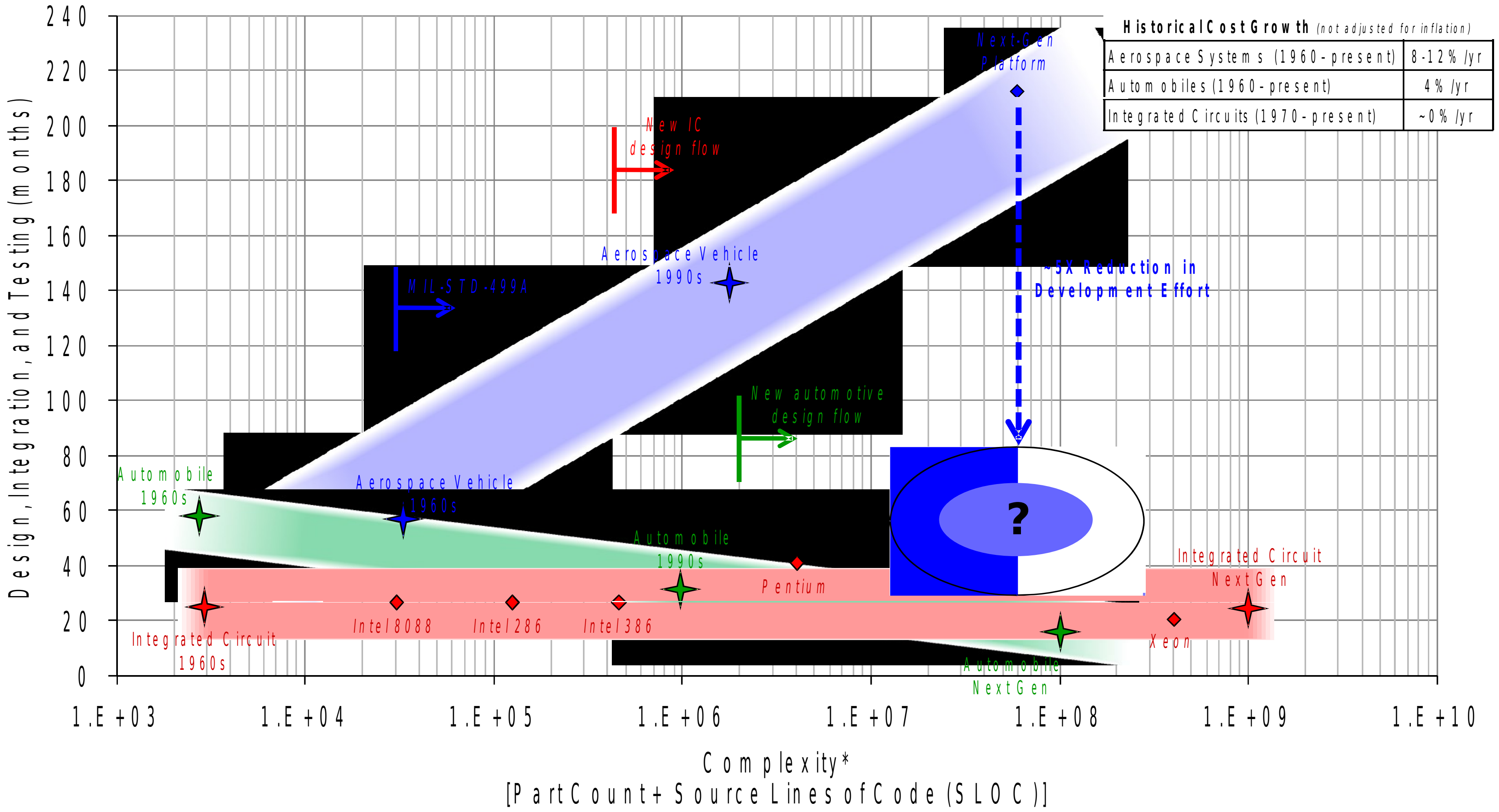
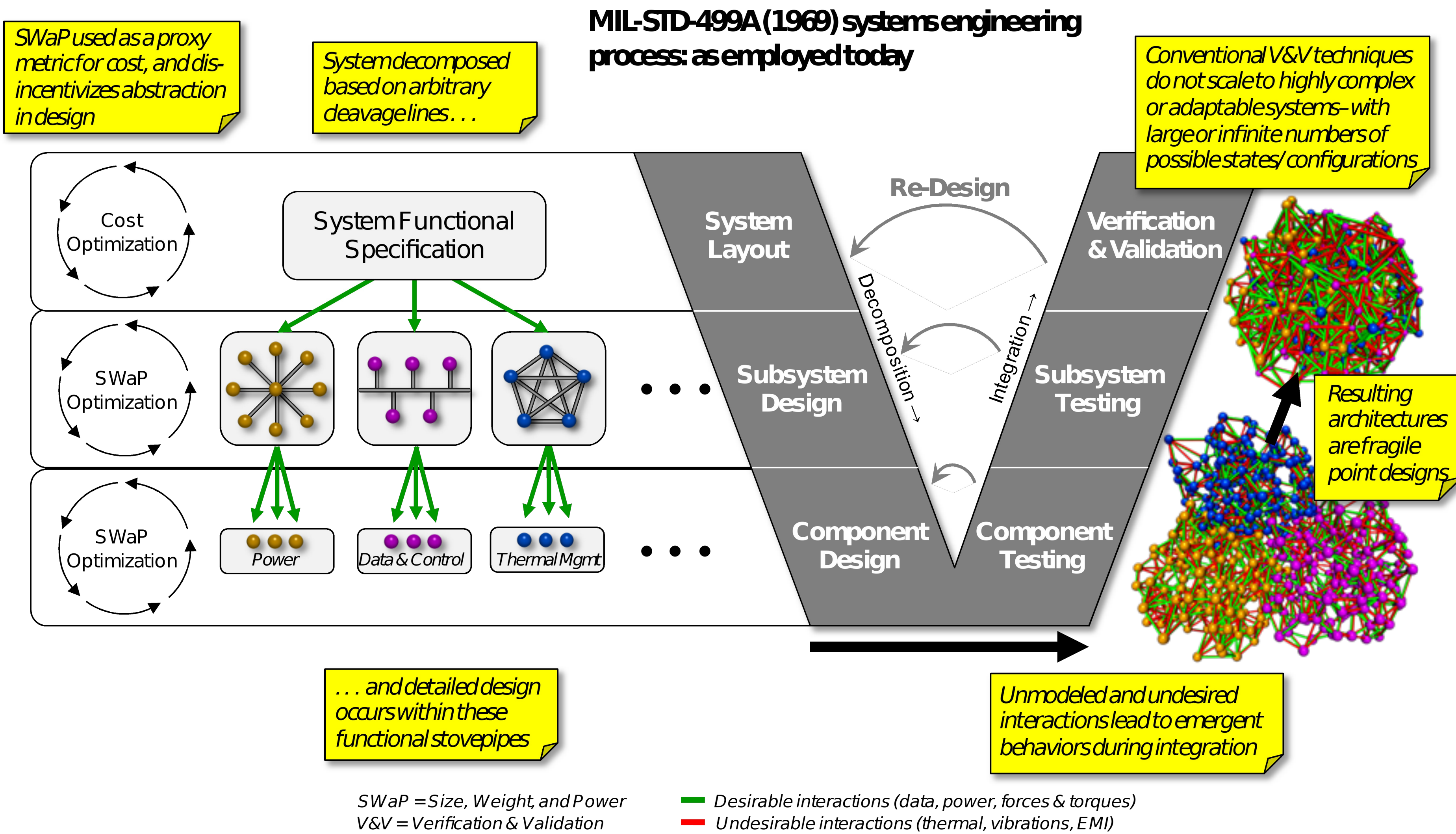
Historical schedule trends with complexity



Historical Cost Growth *(not adjusted for inflation)*

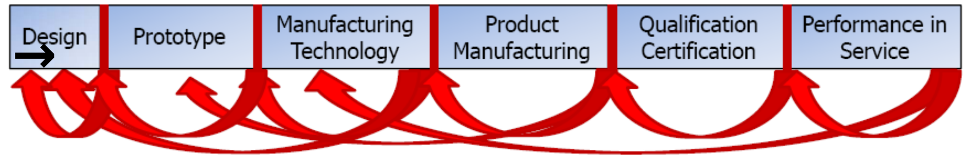
Aerospace Systems (1960-present)	8-12%/yr
Automobiles (1960-present)	4%/yr
Integrated Circuits (1970-present)	~0%/yr

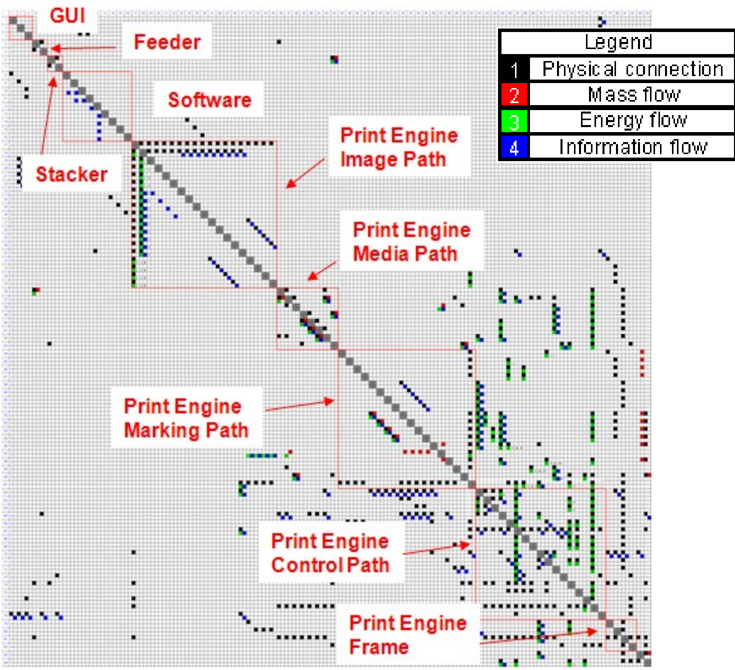
Status quo approach to managing complexity



The technical problem is in the seams

etween stages of production →

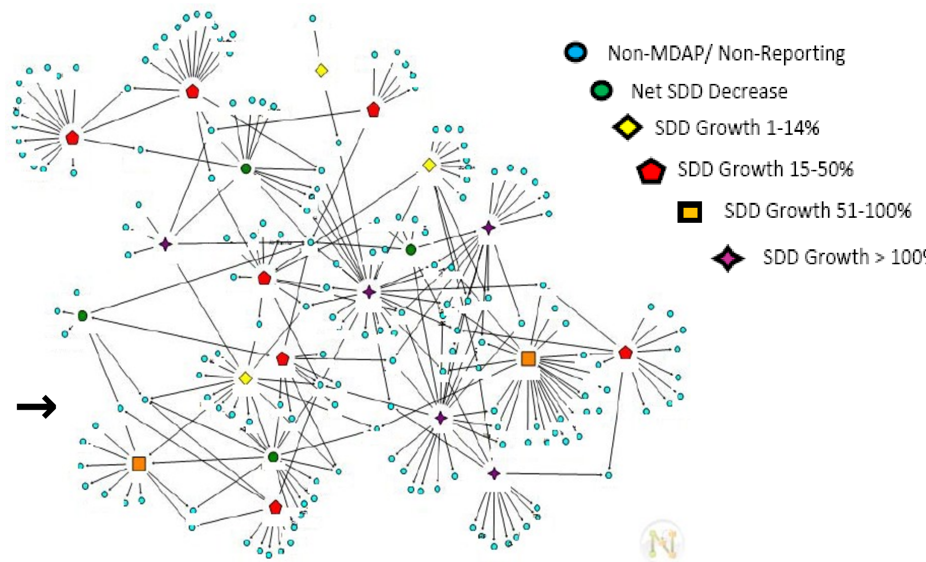




Source: MIT ESD (deWeck et al., 2008)

← Between system components

etween people & organizations →



Source: DDR&E/SE (Flowe et al., 2009)

Adaptive Vehicle Make vision

Shorten development times for complex defense systems [META]

- Raise level of abstraction in design of cyber-electromechanical systems
- Enable correct-by-construction designs through model-based verification
- Compose designs from component model library that characterizes the "seams"
- Rapid requirements trade-offs; optimize for complexity & adaptability, not SWaP

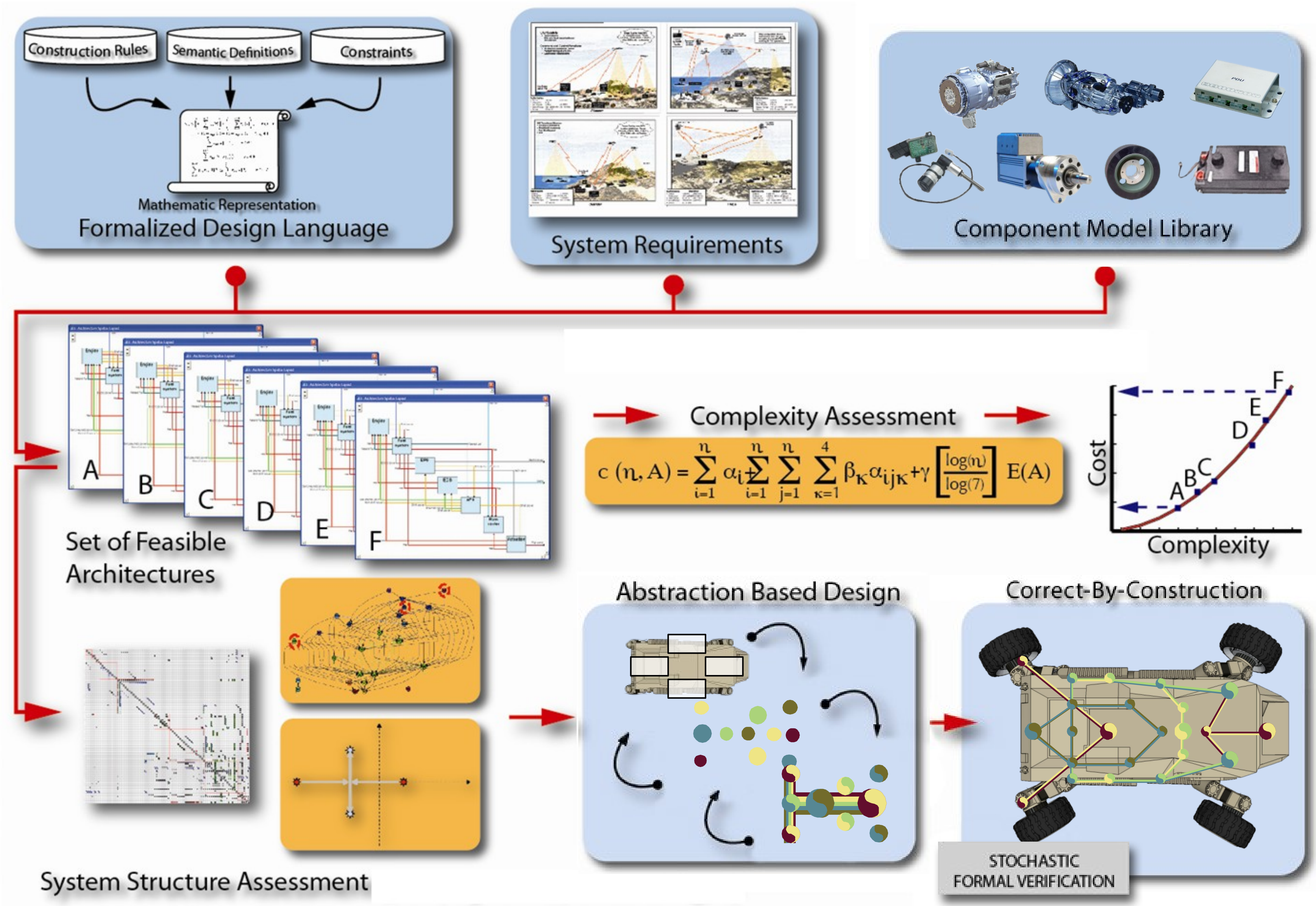
Shift product value chain toward high-value design activities [iFAB]

- Bitstream-configurable foundry-like manufacturing capability for defense systems
- Rapid switch-over between designs with minimal learning curve
- "Mass customization" across product variants and families

Democratize design [FANG]

- Crowd-sourcing infrastructure to enable open-source development of cyber-electromechanical systems [vehicleforge.mil]
- Prize-based Adaptive Make Challenges culminating in an Infantry Fighting Vehicle for testing alongside a program of record [FANG]
- Motivate a new generation of designers and manufacturing innovators [MENTOR]

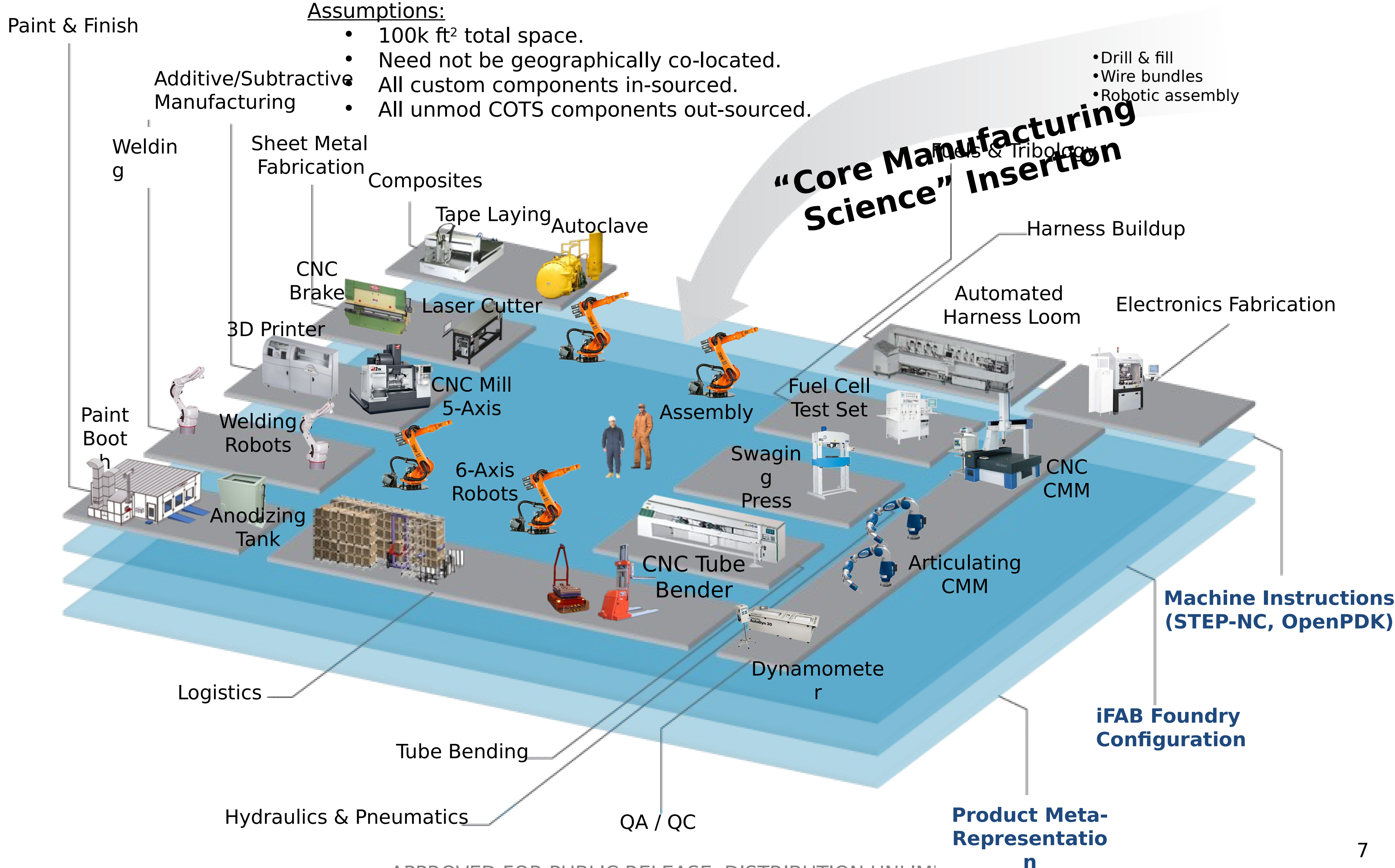
Notional META design flow



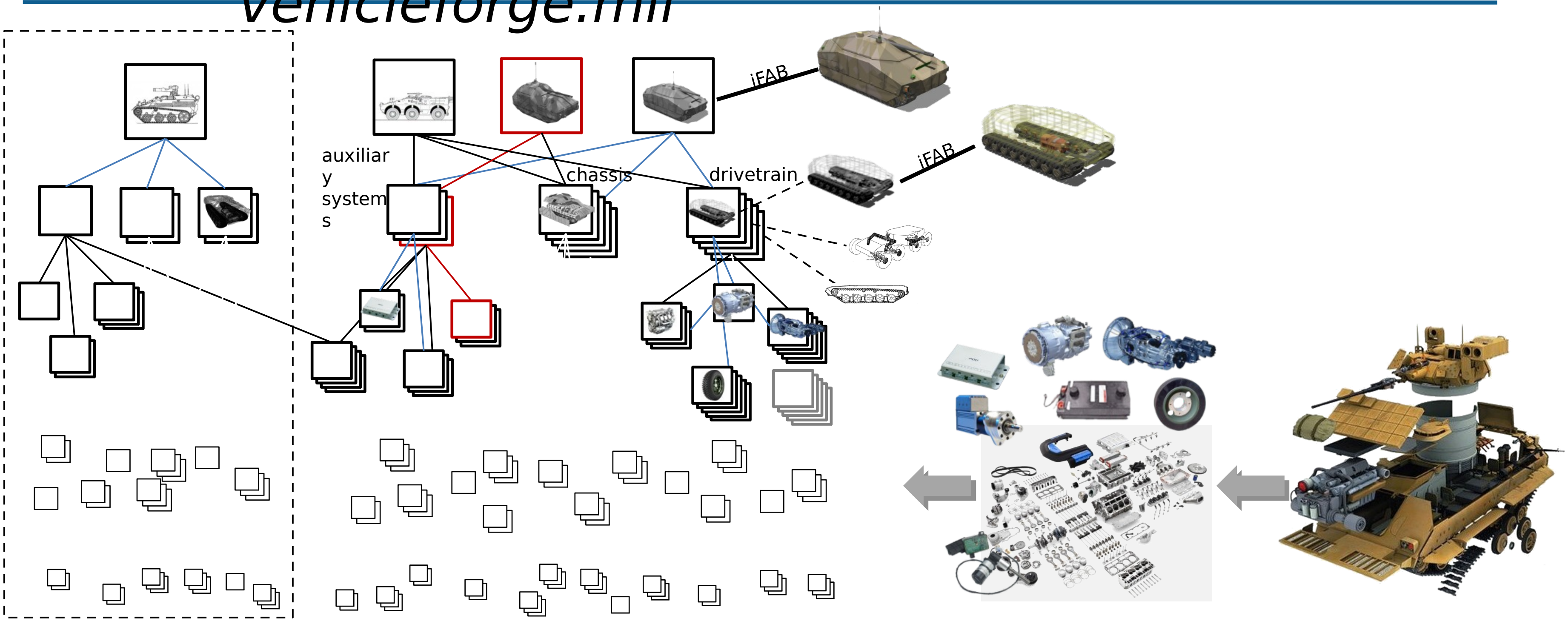
Notional iFAB foundry configuration

Assumptions:

- 100k ft² total space.
- Need not be geographically co-located.
- All custom components in-sourced.
- All unmod COTS components out-sourced.



Crowd-sourcing infrastructure: *vehicleforge.mil*



Estimated Size of Component Model Library

Assembly	Unique Parts (upper limit)	Total Parts (lower limit)	Library Parts (unique x 5)
Drivetrain	3,000	8,000	15,000
Chassis/Armor	5,000	12,000	25,000
Other	7,500	10,000	37,500
Total	15,500	30,000	72,500

Note: Estimates are at the numbered part level. Cables and circuit boards counted as single part. Excludes variable mission equipment, software.

Elements of a Component Model

Physical attributes • size and shape • mass properties • elastodynamics	Undesirable emissions • thermal • electro-magnetic • vibrational
Interfaces • data • power • mechanical	Performance • blackbox model • failure modes

Fast, Adaptable Next-generation Ground vehicle (FANG)

Mobility/Drivetrain Challenge

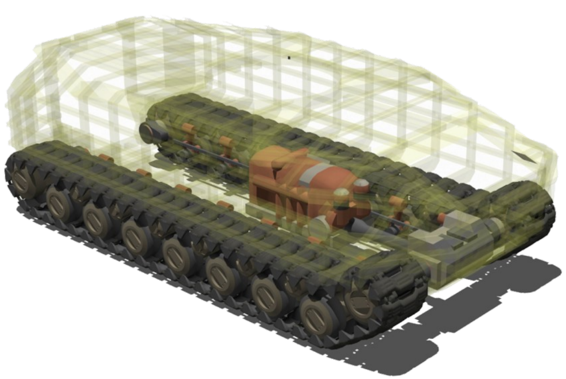
SCOPE
- Vehicle drivetrain to meet IFV speed, efficiency, terrain, reliability objective
- Available model library to include:
  - Hybrid-electric systems
  - Novel ground interfaces

PARTICIPANT POOL
- Global

INCENTIVE
- Prize $1M for winning design
- Winner(s) judged based on multi-objective weighting function

DESIGN AGGREGATION
- Use of META metalanguage required
- Use of vehicleforge.mil optional

BUILD APPROACH
- iFAB foundry build for top design(s)



Chassis/Integrated Survivability Challenge

SCOPE
- Chassis and armor design to meet principal IFV-like survivability objectives
- Available model library to include:
  - Advanced armor concepts
  - Novel configs (monocoque, v-hulls)

PARTICIPANT POOL
- Global

INCENTIVE
- Prize $1M for winning design
- Winner(s) judged based on multi-objective weighting function

DESIGN AGGREGATION
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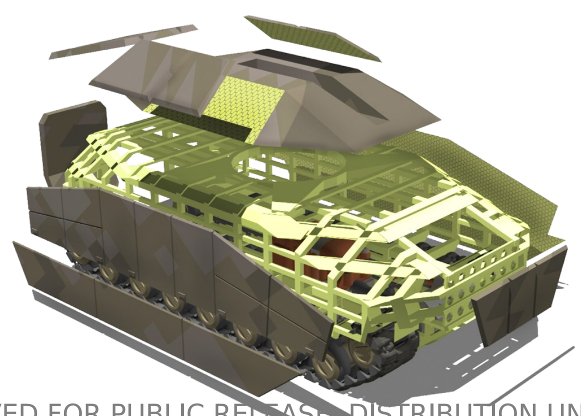


Total Platform Challenge

SCOPE
- Complete IFV based on core Army objectives and distilled requirements

PARTICIPANT POOL
- Global

INCENTIVE
- Prize $2M
- Winner judged based on satisfaction of constraints and multi-attribute preference function (i.e., entirely objective approach)

DESIGN AGGREGATION
- Use of META metalanguage required
- Use of vehicleforge.mil optional

BUILD APPROACH
- iFAB foundry build for top design(s)

Manufacturing Experimentation and Outreach (MENTOR)

Goal

- Educate, motivate, and inspire a next-generation cadre of designers and manufacturing innovators
- Inculcate AVM-type design methods such that they become pervasive in subsequent generations of engineers

Approach

- Design collaboration using modern CAD tools and conventional social networking media
- Distributed manufacturing across networks of schools equipped with various digital manufacturing equipment
- Run competitive prize challenges for design and build of moderately complex systems (e.g. go-carts, mobile robots, small UAVs, etc.)
- Outreach Objectives:
    - 10 schools in CY12
    - 100 schools in CY13
    - 1,000 schools in CY14
- Participation by domestic and foreign schools

Picture credits: Robot image source - gorobotics.net; Los Gatos HS, CA; Loy Norris HS , MI; Stoney Creek HS, CA; Lakeridge HS, OR; New Smyrna Beach HS, FL; Longhill HS, West Sussex, UK; Brockton HS, MA

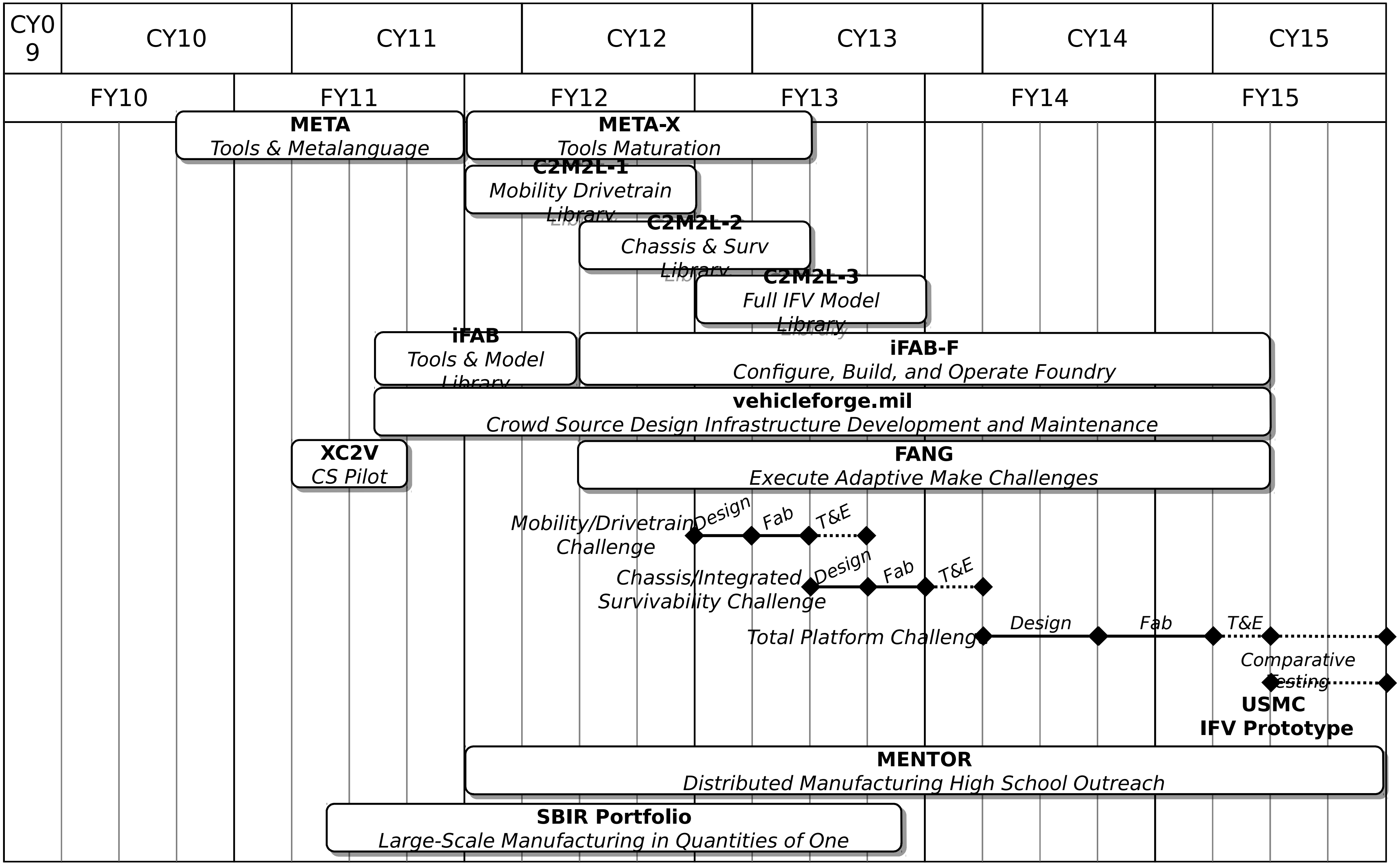
Experimental Crowd-derived Combat support Vehicle (XC2V)

Goal
- Experiment in crowd-sourced design
- Militarily-relevant application
- Existing (simple) commercial infrastructure

Approach
- Utilize existing social network of ~20,000 from Local Motors (increased by ~3,000)
- Crowd-source design of a combat support vehicle
- $10k in prizes
- Build in existing micro-factory

Results
- 159 final designs submitted
- 100 of “high caliber” according to DARPA

AVM Portfolio Schedule



Adaptive Vehicle Make performer community

META

Dassault Systèmes	Extension of commercial CATIA/DELMIA PLM suite to enable formal verification
Vanderbilt Univ (Dr. Bapty)	Compositional cross-domain tool-chain analysis templates that support deep domain analysis
Vanderbilt Univ (Dr. Neema)	Rich model-based approaches developed for software and VLSI into the CPS world
Xerox PARC / CyDesign	Function-based framework for co-verification assessment and reasoning at early stages of design

vehicleforge.mil

GE Research/MIT	Custom collaboration site linking to MIT DOME model repository and social network challenge platform
Georgia Tech GTRI	Collaboration site based on open source distributed version control system; teamed with RedHat
Vanderbilt University	Collaboration site derived from KForge software and information forge site platform
Univ of Pennsylvania	Credentialing users and contributions utilizing reputation-based quantitative trust management

iFAB

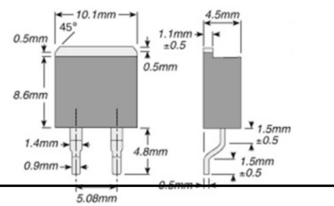
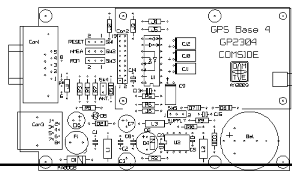
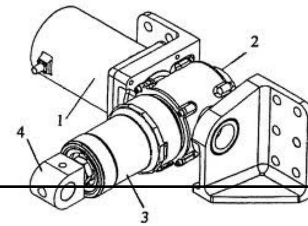
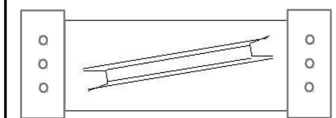
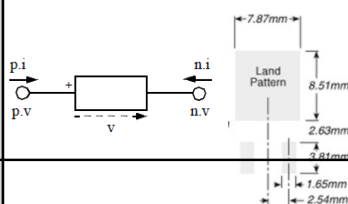
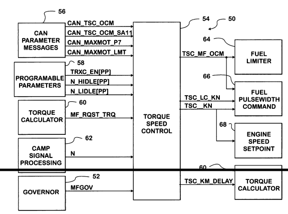
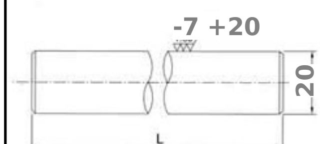
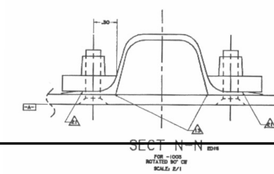
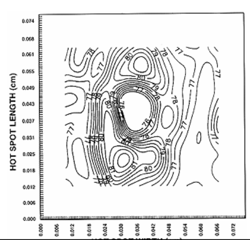
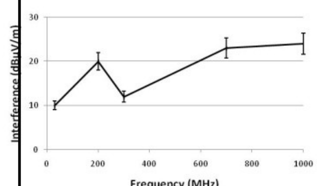
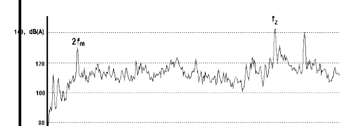
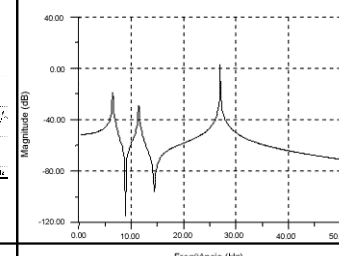
Boeing/General Motors	Manufacturing capability and process model library with describing foundry resources & human actors
Carnegie Mellon Univ	Distributed agents/process model approach for two-way interface between CAD and CAM systems
Intentional Software	Formal "meta meta" language to enable multi-domain co-design of artifact & manufacturing
Penn State ARL	Agent-based foundry configuration and trade space visualization
Univ of Delaware	Developing compositional cross-domain tool-chain analysis templates for composites manufacturing
Xerox PARC	Rapid construction and search of feasible manufacturability spaces and metrics for such spaces
Georgia Tech GTRC	Creating adaptable software libraries of manufacturing processes pertinent to the fabrication of electro-mechanical components and/or assemblies

MENTOR

Georgia Tech/Dassault	Sophisticated distributed manufacturing front-end based on Dassault CAD, low-cost 3D printer network
O'Reilly Media	Novel approach to assembly of complex 3D shapes from 2D media, use of MAKE Magazine, Maker Faires

DARPA™

Example elements of a component model

	Component	Subassembly	Assembly	Structure
Physical attributes • size and shape • mass properties				
Interfaces • data • power • mechanical				
Undesirable emissions • thermal • electro-magnetic • vibrational				
Performance characteristics • blackbox model